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SUGGESTED PROCEDURES AND GUIDES FOR AN ANALYSIS OF PRESENT AND FUTURE RATES OF SEDIMENTATION FROM NATIONAL FOREST LANDS IN THE PUERCO-RIO SALADO

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FOREST SERVICE

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By

E. J. Dortignac

Watershed Management,
Washington Office

July 1962

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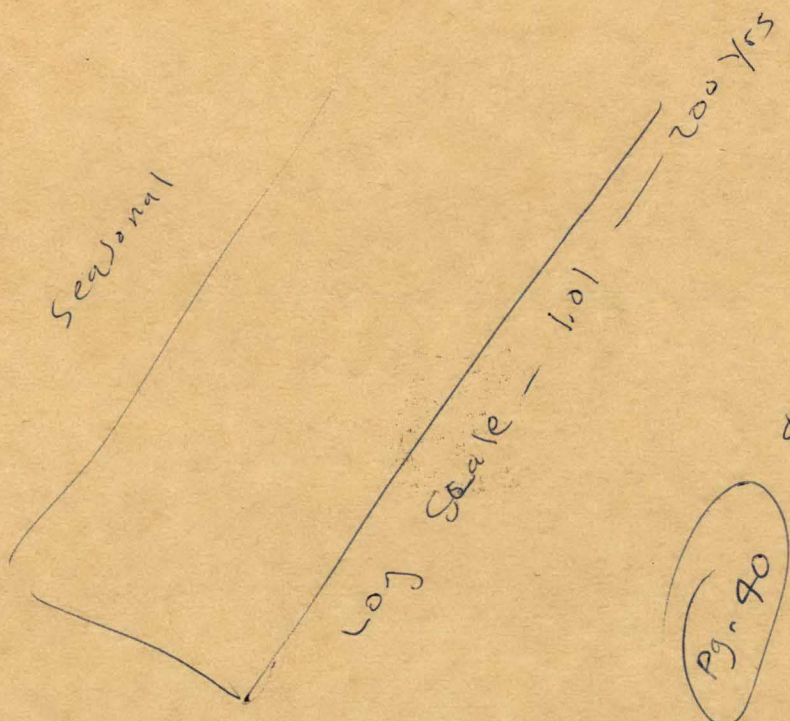
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INTRODUCTION

The Corps of Engineers has been requested by the Resolution Committee on Public Works (U. S. Senate) to prepare a review report of House Document 243 - 81st Congress to determine whether any additional structures or works should be undertaken in the Rio Grande and its tributaries, with particular reference to the Rio Puerco and Rio Salado drainages. As a consequence, the Corps has requested from the Forest Service, the quantity of sediment reduction (from National Forest lands on these 2 drainages) that might be expected under a complete land treatment and management program. This information may influence the location, design, and cost of any downstream sediment control structures that might be proposed by the Corps of Engineers.

The Forest Service recognizes the need for a careful and reliable analysis as a basis for a sound report. It is anticipated that the final Forest Service report will undergo considerable scrutiny by other agencies and must, therefore, be based on sound hydrologic procedures and analyses. Also, it is recognized that factual data obtained in this study will provide a basis for:

(1) land management and treatment programs for reduction of downstream sedimentation on these drainages

(2) improvement of forage, timber, wildlife, recreation and other resources on these drainages

(3) development of guides, procedures, and methodology that may be useful in future hydrologic analyses on National Forest lands

REVIEW OF CROFT'S REPORT

Lowell G. Woods, Chief, Division of Watershed Management, and his staff, have recognized the importance of this project. As a first step, A. R. Croft, an eminent watershed management consultant was hired to:

(1) make an extensive reconnaissance of watershed conditions on National Forest lands within the Rio Puerco and Rio Salado drainages

(2) design a plan for the conduct of a watershed condition survey for the purpose of determining sediment production, treatment measures needed for erosion control, and the amount of sediment reduction that can be expected from such treatment

A report by A. R. Croft[1/] outlines the information needed to guide the proposed watershed condition survey. This is a very good report and sets the stage for designing specifics.

My report is an attempt to utilize and combine all of the information and philosophy contained in Croft's report with my own knowledge and experience of watershed hydrology and behavior in the Rio Puerco-Rio Salado and with all pertinent information that is available in developing suitable methods, procedures, and guides. Additionally, I have outlined some suggestions for the study of presently available data. It is believed that the evaluation of these data prior to undertaking a field survey of hydrologic conditions may prove rewarding.

1/ Suggestions for a Reconnaissance Survey of Hydrologic Conditions and Sediment Yield of National Forest Lands in the Rio Puerco and Rio Salado Drainages, New Mexico by A. R. Croft, Consultant, Forest and Range Hydrology - June 1962

Before outlining suggested methods and procedures for the proposed survey and analysis of data it appears desirable to summarize Croft's report with particular attention to specific recommendations. Some discussion on pertinent points appears needed.

RESTORATION MEASURES AND GRAZING MANAGEMENT

Croft discusses in general terms the advisability of several restoration measures that might be considered. He concludes that seeding, erosion control on roads and trails, chiseling and pitting, sloping of arroyo and gully walls, major sediment dams, and contour-trenches can have little effect on overall sediment reduction and that effective grazing management is much more promising, per quote:

"It is my opinion that effective grazing management in the long-run, can have more effect on reducing sedimentation than all other practices combined. This is because the practice can be made effective over a major portion of the area; whereas, most of the other practices, even though they may be highly effective, can be applied only to rather limited areas."

I agree that effective grazing management is essential before embarking on any program of soil and vegetation treatment. But land treatment will be needed on most deteriorated sites in the Rio Puerco-Rio Salado. Management alone will not do the job of adequately reducing damaging runoff and sediment during the next 100 years.

It appears that the above philosophy may represent some of our former "thinking" that good range management is good watershed mmanagement and that good forest management is good watershed management. Research has indicated this is not always so. If we are ever going to establish watershed management on the National Forests we shall need to recognize and emphasize these differences.

Croft's report represents a careful appraisal and some logical thinking by a well-qualified watershed management scientist. His unfamiliarity with the actual conditions within these watersheds may warrant additional clarification. These are briefly discussed:

RIO PUERCO AREA

"Rio Puerco is substantially less than 10 percent of the Rio Grande - Croft".

The Rio Puerco represents 28 percent of the "contributing" Rio Grande Basin in New Mexico above Elephant Butte Reservoir or 23 percent when Colorado is included. It is less than 10 percent if we consider the Rio Grande downstream in Texas.

The important fact from our standpoint is that the Rio Puerco which represents 28 percent of the area in the live Rio Grande drainage in New Mexico above Elephant Butte Reservoir contributed about 45 percent of the sediment and only 4 to 6 percent of the measured water yield to 1950. In contrast, the Rio Salado produced about 10 percent of the measured sediment into the Rio Grande and considerably less measured runoff. The above may influence the emphasis or concentration of work in these respective drainages.

It may be desirable to bring the above information up-to-date. Also, you may wish to have available the channel losses in runoff when proceeding downstream in the Rio Puerco. This kind of information is not available for the Rio Salado since only one gaging station (near mouth) has been operated on this drainage.

RANGE AND TIMBER SURVEY DATA

"Vegetation types are probably in more detail than practical for the proposed reconnaissance survey - Croft".

Data contained in these two surveys may be extremely useful in the hydrologic analysis. A critical examination of these data may prove useful in setting up criteria and for determining the kinds of information needed in the proposed hydrologic survey. Also, the Zuni Soil Survey should contain some pertinent information.

VEGETATION TYPES

Vegetation types by Cooperrider and Hendricks - 1937 need some modification.

Semi-desert grasslands

This type is of minor extent on National Forest lands and should probably be discarded.

Savanna woodlands

This classification is too broad. Oak brush is contained herein. This vegetation type is associated with the dense pinyon-juniper or ponderosa pine zones, a result of fire.

Pinyon-juniper-sagebrush lands are the main contributors of surface runoff and sediment from National Forest lands. Therefore, a more detailed breakdown and classification seems needed. Particularly since an increase in vegetation volume can be expected to result in a decrease in depth of flood runoff. As a start, we might consider the following classification based on the areal extent of crown coverage:

Type	$\frac{\text{open area}}{\text{tree covered area}}$
Open woodland	More than 2.0
Thin woodland	Between 0.7 - 2.0
Dense woodland	Less 0.7
Brush woodland	—

Woodland = pinyon-juniper

Brush = sagebrush, rabbitbrush, and gambel oak

The above criteria for defining woodland refers to crown cover. Thus, a ratio of 0.5 means twice as much land area covered by tree crowns as in the open, while a ratio of 2.0 means twice as much open area. Percent of open area might be used but does not appear as meaningful without additional descriptive material.

Suitability of the above standards should be tested in the office by use of aerial photos. The listed classes may be too broad or too narrow.

You may wish to consider tree stature as well as crown cover since crown volume influences precipitation interception, raindrop impact, contribution of tree litter, herbaceous cover, pattern of grazing use, etc.

We have some research information on range condition, infiltration rates, erosion rates, and soil characteristics for the above types in the Upper Rio Grande Basin. These data were collected in 1953-54 inside and outside exclosures established on the National Forests in 1941-42. Some of these data were released in the Rocky Mountain Station's Annual Reports.

Pine-fir forest

Contains ponderosa pine and mixed conifer. Separation of these 2 types might be considered. The erosion hazard is greater in the ponderosa pine type.

Spruce-fir forest

A satisfactory breakdown, but should recognize that the mountain grassland and aspen contained, herein, have distinctly different hydrologic characteristics.

HYDROLOGIC CONDITION CLASSES

Class I - Pristine

This class can be eliminated because it is entirely absent.

Moreover, it cannot be considered an ultimate objective. All of the National Forest lands within these drainages have been intensively used in the past. These lands can be expected to be used even more so under our multiple use program geared to the rapidly increasing population.

Class I might represent the maximum potential for the given site. The soil scientist and plant ecologist working jointly can determine this classification. Site potential was considered in the Zuni Soil Survey.

Class II, III, and IV

Slightly, moderately, and excessively deteriorated vegetation and soil conditions may be suitable. However, these descriptive relative terms should be defined in terms of the hydrologic characteristics of soil and vegetation. Definite standards are needed to provide uniformity between workers in the field as well as in analyzing and interpreting data in the office.

Class V

This is a good classification. The length, depth, and areal extent of gullies on the National Forests should be determined by soil groups, vegetation conditions, etc. Additionally, extent of runoff source areas above headcuts, channel gradients, and other factors should be determined.

That gully and arroyo trenching produce tremendous quantities of sediment can be gleaned from the estimated average annual soil loss from arroyos and channels in the Puerco. The volume of the Rio Puerco channel increased 250,000 acre-feet from 1885 to 1939. The average annual soil loss was 4630 acre-feet during this period. The volume of soil washed out of tributary gullies has been estimated at 6440 acre-feet annually between 1885 and 1927. Thus, according to surveys of the arroyos and channels, more than 11,000 acre-feet of soil has been removed annually on the average for the above-listed time periods.

It is generally recognized that arroyos and gullies are the source of most of the sediment reaching the main Rio Grande channel. An analysis by the Soil Conservation Service indicated that most sediment is derived from gullies and trenching arroyos. Contribution according to type of erosion was:

Source of sediment	Total sediment load percent
Gully and arroyo trenching	65
Sheet erosion	30
Wind erosion	5

It is believed that wind erosion contributes more sediment than indicated above. Soil movement through wind action is emphasized during drought periods, such as experienced between January and July 1962.

Another important consideration is that gully and arroyo trenching is to a large extent dependent on runoff from the higher lying pinyon-juniper lands. Though pinyon-juniper areas may contribute less soil to the total sediment load, than lower-lying areas, runoff water from woodlands is an important contributor to arroyo and gully trenching downstream. This contribution should be determined. It may not be so difficult. We know sediment is related to runoff. How and when needs to be determined. Runoff from snowmelt should be separated from measured runoff from rainstorms. This is discussed later in detail.

APPENDICES

Croft's report includes 8 appendices:

Appendix I - selected references

Appendix II - comparison of vegetation-erosion conditions from USDA Tech. Bull. 567, 1937.

Appendix III - criteria for classification of watershed lands on the basis of their hydrologic condition

Appendix IV - some measured sedimentation rates (acre-feet/sq. mile/year)

Appendix V - estimated annual sediment yield by vegetation types and hydrologic condition classes Rio Puerco and Rio Salado drainages (from Appendix I and IV)

Appendix VI - form for compiling soil type, hydrologic condition, and estimated sediment yield

Appendix VII - form for compiling estimated reduction in sediment yield as a result of proposed restoration measures

Appendix VIII - suggested format for report

The descriptions in Appendix III for guidance of hydrologic condition classes apparently have no relation to vegetation type, soil type, nor to climatic conditions. Ground cover criteria may need some revision. Class IV, advanced deterioration of vegetation and soil, lists a ground cover varying from 10% to 30%. Most of the pinyon-juniper lands will probably average less than 10% ground cover. Ground cover on the San Luis experimental watersheds is 5% or less.

FACTORS TO CONSIDER IN THE HYDROLOGIC SURVEY AND ANALYSIS

In determining methods and procedures certain basic premises must be made. These are discussed.

1. Proposed location of dams

Rio Puerco - probably upstream; one on the main Puerco below the confluence with the Chico Arroyo and one on the Rio San Jose above the mouth

Rio Salado - near the mouth

Runoff and sediment gaging stations are located at the above sites. Also, these gaging points are nearest the National Forest boundaries

2. LIFE OF DAMS (100 YEARS)

Computing sediment reduction over a 100 year period should prove more advantageous than the previously used 50 year life of structures.

3. PRECIPITATION

3.1 Runoff and sediment are dependent on type, amount, distribution, and rate of precipitation as well as on the hydrologic characteristics and conditions in the watersheds. Therefore, a critical analysis of the precipitation on National Forest lands is needed

3.2 An analytical estimate of precipitation expectancy in regard to maximum probable rainstorm, maximum probable snow accumulation, and maximum rainfall intensities and duration should be made.

3.3 An estimate of expected dry and wet periods during the next 100 years would be helpful. We experienced a wet period prior to 1942. The drought commenced in 1942 in the Upper Rio Grande - apparently we are still in the dry period. This sequence of wet and dry years must be considered since the quantities of runoff and sediment are so much greater in wet periods. Average annual suspended sediment loads in the Upper Rio Grande amounted to 39 million tons between 1936 and 1941 whereas in the 3 dry years 1948 through 1950 it was only slightly more than 7 million tons or about one-fifth as much.

3.4 Santa Fe has the longest precipitation record in the State and should be used in the long-term analysis. Tree ring and pollen data also are available.

The 25, 50, and 100 year rainfall expectancy patterns were computed for Santa Fe which is in the pinyon-juniper zone. These data are included in the publication "Watershed resources and problems of the Upper Rio Grande - 1956 - Rocky Mountain Station. The probable

storm patterns for the Rio Puerco-Rio Salado should be computed using the same or modified procedures.

4. RUNOFF

4.1 Runoff from National Forest lands are of 2 types:

4.11 Snowmelt runoff - mostly above 8000 feet elevation contributes practically all of the runoff measured downstream in Dec., Jan., Feb., Mar., April, May, and sometimes during the first half of June. The main Rio Puerco was flowing from 2/1/62 to 6/15/62. No rain fell during this period. Runoff and sediment produced during this period can be attributed to National Forest lands. This can be checked by 2 methods:

4.111 Determine whether existing stations measured any rainfall amounts during these periods and whether warm spells alone caused melting of snow

4.112 Plot hydrograph of mean daily discharge for Dec. through mid-June. Runoff from rainstorms, if any, will show as separate peaks on the hydrographs

4.12 Surface runoff - from summer and fall torrential rains comes mostly from below 8000 feet elevation. Runoff source areas are ponderosa pine in poor hydrologic condition and most of the pinyon-juniper woodland.

4.2 Runoff is related to precipitation

4.21 Quantity of water in the snowpack largely determines the amount of spring runoff

4.22 Timing of spring runoff is mostly dependent on temperatures. Occasionally, spring rain falling on snow accelerates snow melting.

4.23 Rainfall intensity may be more important than total rainfall in determining surface runoff

4.24 Rainfall - excess can be computed for design storms if the infiltration capacities of soil-vegetation complexes are known. Computed rainfall excesses are directly related to surface runoff but not equal to it because re-absorption and channel losses reduce downstream flow.

5. SEDIMENT

5.1 Waterflow from snowmelt is clear when leaving the spruce-fir zone; may be slightly turbid when leaving the ponderosa pine zone in local deteriorated areas; picks up some sediment in the pinyon-juniper type; and finally picks up most of the sediment from downstream arroyos or gullies. This can be estimated from existing data and might be checked on sample watersheds this summer

5.2 Bluffs, breaks, escarpments, etc. produce maximum quantities of runoff and erosion. Rock outcrops produce considerable runoff. This probably was true even under pristine conditions. Plans to control or dissipate this excess flow by means of levees, dikes, water spreaders, debris basins, soil ripping, and vegetation improvement should be considered.

Roads, trails, and stream channels contribute runoff varying from 90 to 95% or more of the total rainfall. These are high runoff areas in contrast to arroyos and gullies which are high sediment source areas. These areas need to be mapped, classified and delineated separately. Proximity of these high runoff areas to channels and waterways is an important consideration.

5.3 Sediment production is related to runoff. Average annual runoff should be related to average annual sediment production. Various factors become integrated, when an annual basis is used. Excellent relationships were obtained for the San Juan, Colorado, and Green Rivers above Lee Ferry, Arizona. Good relationships were obtained on the San Luis watersheds on a seasonal basis. Good correlations were obtained for certain periods of flow in the Fuerco. Using seasonal runoff instead of annual runoff is recommended as snowmelt runoff should be separated from rainfall runoff.

5.4 An estimate of sediment rates from National Forest lands may be obtained from deposition in:

Bluewater reservoir
Stock tanks
Basalt flow (recent)

The USDA flood control report states the Rio San Jose above McCarty is non-contributing in regard to floods and sedimentation. This needs further checking and verification.

5.5 Photographs and gully measurements

Numerous photographs and gully cross-sections were taken by Cooperrider's staff and the SCS technicians. If these data can be located, repeat photos and re-measurement of gullies may provide rates of soil losses and deposition.

6. HYDROLOGIC CONDITION

Runoff is directly related to the hydrologic condition of the watershed. Hydrologic condition is a function of vegetation and soil characteristics. Vegetation and soil characteristics which can be altered by man and his animals are the important factors in regard to runoff and sediment reduction.

6.1 Vegetation characteristics needed for hydrologic analysis of present and future conditions: type, composition, density (no. plants per unit area), stature, ground cover including litter, quantity of dead and live organic materials

6.2 Soil characteristics needed for hydrologic analysis of present and future conditions: group (broader classification than type), parent material, depth to bedrock, water storage capacity, non-capillary porosity (0-3" or restricting layer) 2/, erodibility index, and susceptibility to piping. The latter is not only important in estimating sediment production but also in prescribing satisfactory treatments

7. OTHER WATERSHED CHARACTERISTICS

Other important watershed characteristics are needed for estimating runoff and sediment, routing flood flows, for planning land improvement structures and for prescribing soil and vegetation treatments. These are: Geology, geomorphology, slope (gradient and length), and aspect or exposure.

2/ A soil penetrometer might be useful for obtaining an index of porosity or restriction of infiltration and percolation

8. LAND USES

Present and potential land uses should be known. Potential use, estimated on the basis of the information on multiple uses, would prove useful

8.1 Grazing

Pinyon-juniper provides most of the grazing capacity on the Cibola and Santa Fe National Forests. This was determined by Springfield's analysis of range allotments on these forests. It is suggested that a similar analysis be conducted from range allotments within the Rio Puerco-Rio Salado drainages. This will require compiling data from cards filed in the supervisor's office. This information will provide a basis for determining the need for modification of grazing methods, seasons, amounts, etc. A revision of the priority of work on range allotments may be needed.

Range improvements such as seeding, constructing stock tanks, and noxious plant control might be considered. These can increase the grazing capacity, improve vegetation condition, and result in a reduction of runoff and sediment.

Gently sloping lands (less than 15% slope) when seeded to crested wheatgrass or other desirable grasses would allow removal of livestock from steeper and more erodible lands.

8.2 Timber Harvest

Runoff from snowmelt can be expected to increase upwards to a maximum of 30% after cutting of timber. The effect of this increased runoff on mountain stream channels and downstream arroyos should be evaluated

9. FIRE, INSECTS, AND DISEASES

Runoff and erosion can be expected to increase considerably after a fire. May need to provide increased protection. An insect or disease epedemic would likewise result in increased runoff.

10. SOIL AND VEGETATION TREATMENTS

10.1 Ripping - studies indicate surface runoff is reduced 95-98% during the first year and from 80 to 90% in the third year after treatment without any vegetation improvement. Appreciable erosion reduction is likewise obtained.

10.2 Detention reservoirs - good flood control structure - extremely useful above active headcuts. Can serve dual purpose - runoff retention and water for livestock and game.

10.3 Water spreaders and dikes - most valuable below bluffs or breaks - delays flows but fails to reduce quantity of flows except on areas of high infiltration capacities

10.4 Contour trenches - most useful on steep, excessively eroding slopes

10.5 Seeding - necessary with above mechanical treatments. Annual cover crops (barley and rye) may be needed on difficult sites to establish desirable grasses, shrubs, and trees. Might consider seeding alternate strips on the contour to provide a source of seed.

10.6 Gully control

Different treatments needed where soil piping is present. Should consider filling in gullies or sloping sidewalls of gullies as well as runoff retention, retardation and diversion

10.7 Noxious plant control - mechanical and chemical control of noxious plants should be considered as a means of restoring or establishing a satisfactory cover of vegetation

PRE-SURVEY ANALYSIS AND EVALUATION

A comprehensive analysis of existing data prior to undertaking the field survey might prove quite rewarding. Some of the needs previously mentioned might be available. Also, such an analysis and evaluation could result in a material improvement of field survey methods and assure collection of pertinent field data.

Analysis of existing precipitation, runoff and sediment data within and surrounding the Rio Puerco-Rio Salado will provide the basis for interpreting and using information collected in the field survey. Considerable data are contained in the files, reports, and publications of the following agencies: Weather Bureau, Geological Survey, Corps of Engineers, Bureau of Reclamation, Soil Conservation Service, Bureau of Land Management, Bureau of Indian Affairs, Agricultural Research Service, Rocky Mountain Station, New Mexico State Engineer's Office, Inter-state Stream Commission, New Mexico State University, University of New Mexico, and Elephant Butte Irrigation District (John Gregg).

U.S.G.S. water supply papers have summarized considerable runoff and sediment data. Sedimentation data (1948-57) are published in water supply papers 1133, 1163, 1188, 1199, 1252, 1292, 1352, 1402, 1452 and 1522. More recent data may be obtained from Mr. Stow, Chief, Water Quality, U.S.G.S., University of New Mexico. Earlier data are included in: U. S. Department of Interior, 1950 Middle Rio Grande Project, New Mexico, U. S. Cong., 81st, 2nd Sess., H. Doc. 653, 346 pp., illus.

Examination of range allotment analyses, timber surveys and harvesting plans, Zuni soil survey, fire control surveys and plans, etc. may reveal pertinent information on present and future hydrologic conditions as well as possible treatments.

The USDA flood control reports (1941 and 1951) contain some pertinent information.

Re-measurement of soil and vegetation conditions in 1962 of sampling points used in the earlier surveys should provide an indication of long-term trends. Field data collected by Cooperrider and Hendricks (1937) in their field survey might likewise be utilized.

FIELD SURVEY AND METHOD OF SAMPLING

Croft's proposal for sampling small sub-watersheds is excellent. Size and number of sub-watersheds is unimportant. Sub-watersheds should represent all of the important hydrologic conditions found in the Rio Puerco-Rio Salado drainages. Information gathered in the

field survey will need to be extended to cover all National Forest lands. This may be accomplished through use of vegetation, soil, geology, climatic, topographic, land use and other maps combined with aerial photographs.

As a start, it is recommended that representative sub-watersheds be selected along headwaters of 4 main drainages:

Rio Puerco above Cuba (Santa Fe National Forest)

Chico Arroyo (Cibola National Forest)

Rio San Jose (Cibola National Forest)

Rio Salado (Cibola National Forest)

At least one sub-watershed is needed for each important hydrologic type.

Sub-watersheds should be selected to represent the hydrologic type. USGS topographic quadrangles, planimetric maps, geology and soils maps, and aerial photos can be used in the preliminary selection of sample watersheds. Field reconnaissance and surveys should be used to check the validity of sub-watershed selection.

In this regard, you may wish to consider using one or more sub-watersheds in an evaluation program. If so, information obtained in the field survey will serve a dual purpose. Also, data collected on precipitation, runoff, and sediment production might be used in calibration of the watersheds.

It may be desirable to add one or more members to the suggested field crew. The addition of a hydrologist seems desirable.

Crew members should work as a team and compliment one another's skills. Moreover, this type of teamwork should provide excellent training and experience for all crew members.